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Standardization of ghee residue-enriched chocolate coating for the manufacture of enrobed chocolates

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Abstract

Chocolate coating is an important determinant of the sensory, compositional and textural quality of enrobed chocolates, and optimization of its formulation is essential for producing a product with desirable quality attributes. The present study aimed to standardize ghee residue enriched chocolate coating for manufacture of enrobed chocolates by optimizing the ratio of dark chocolate (75% cocoa) (PDC) and dark compound chocolate (DCC), followed by incorporation of different levels of ghee residue. Out of five coating formulations, the coating containing 75% PDC and 25% DCC exhibited the highest overall acceptability and was selected for subsequent optimization. The selected chocolate blend was then incorporated with 25, 30, 35 and 40 percent ghee residue in the coating to determine the optimum incorporation level. Ghee residue significantly ($p < 0.05$) influenced the compositional and textural characteristics of enrobed chocolates, whereas colour and appearance and flavour were not significantly affected ($p < 0.05$). Amongst the experimental samples, the coating containing 35 percent ghee residue exhibited the highest overall acceptability (8.73) along with desirable body and texture (8.74), moisture (4.55%), fat (26.69%) and balanced textural characteristics. Based on the overall sensory, compositional and textural characteristics, the coating formulation containing 75 percent dark chocolate (75% cocoa), 25 percent dark compound chocolate and 35 percent ghee residue was identified as the optimum formulation for the preparation of enrobed chocolates.

Keywords: Enrobed chocolate, chocolate coating, dark chocolate, dark compound chocolate, ghee residue, cocoa

Introduction

Chocolate is one of the most widely consumed confectionery products because of its distinctive flavour, smooth texture and high consumer acceptability. It is produced from the beans of *Theobroma cacao* L. and is commercially available as dark, milk and white chocolate depending on the proportions of cocoa solids, cocoa butter and milk constituents (Afoakwa, 2016) [1].

Consumer awareness of the relationship between diet and health has accelerated the demand for functional foods enriched with bioactive ingredients. Owing to its desirable sensory attributes and widespread consumer acceptance, chocolate has emerged as an attractive food matrix for incorporating bioactive ingredients. The increasing demand for healthier and functional foods has encouraged the development of value-added chocolate products enriched with vitamins, minerals, probiotics, dietary fibre and plant-derived bioactive compounds. However, incorporation of these functional ingredients may alter the physicochemical, rheological and sensory properties of chocolate, making formulation optimization essential to ensure product quality and consumer acceptability (Faccinotto-Beltran *et al.*, 2021) [8].

Among different types of chocolate, dark chocolate has attracted considerable scientific interest because of its high cocoa solid content and abundance of bioactive compounds, including flavonoids, catechins and procyanidins. These compounds exhibit potent antioxidant activity and have been associated with several health-promoting effects, such as reducing oxidative stress and improving cardiovascular health. Consequently, dark chocolate has become a preferred base for the development of functional chocolate products (Samanta *et al.*, 2022) [17].

Ghee residue is a nutrient-rich dairy by-product obtained during the manufacture of ghee and contains appreciable amounts of milk fat, protein, phospholipids and minerals.

During the clarification process, Maillard browning and caramelization reactions generate characteristic cooked and nutty flavour compounds, which enhance its suitability for food applications (Vashisht and Meena, 2018) [19]. Owing to its nutritional composition and desirable flavour, ghee residue has been successfully utilized in bakery, dairy and traditional food products, demonstrating its potential as a value-added ingredient while promoting the sustainable utilization of dairy by-products (Saji *et al.*, 2023) [16].

Chocolate coating plays a vital role in determining the appearance, gloss, snap, mouthfeel and overall sensory acceptability of enrobed confectionery products. Dark chocolate is characterized by a higher cocoa solid content and intense cocoa flavour, whereas compound chocolate is manufactured by replacing cocoa butter partially or completely with vegetable fats, resulting in improved processing stability and ease of handling (Beckett, 2019) [2]. Therefore, standardization of the proportion of dark chocolate and compound chocolate is essential for obtaining a coating with desirable sensory and textural characteristics for enrobed chocolates.

Alterations in the fat composition of chocolate influence cocoa butter crystallization, melting behaviour and textural characteristics (Timms, 2003) [18]. Since ghee residue is rich in milk fat, its incorporation into the chocolate matrix may modify the fat phase and consequently influence crystallization behaviour, melting characteristics and texture. Therefore, optimization of the level of ghee residue incorporation is essential to obtain a coating with desirable physicochemical, textural and sensory characteristics.

Although the nutritional and technological potential of ghee residue has been demonstrated in dairy and bakery products, information regarding the incorporation of ghee residue into chocolate coating formulations is limited. In addition, studies on the standardization of blended dark chocolate-compound chocolate coatings enriched with ghee residue for enrobed chocolate are scarce. Therefore, the present study was undertaken to standardize a ghee residue-enriched chocolate coating by optimizing the proportion of dark chocolate (75% cocoa) and dark compound chocolate, followed by evaluation of different levels of ghee residue incorporation. The developed formulations were assessed for sensory, compositional and textural characteristics to identify the most suitable coating formulation for the preparation of enrobed chocolate.

Materials and Methods

Raw Materials

The ingredients used for preparation of enrobed chocolate coating included dark chocolate (75% cocoa) (PDC), dark compound chocolate (DCC) and ghee residue. Both PDC and DCC were procured from Amul Dairy, Anand, Gujarat, India. Ghee residue was obtained while preparation of ghee by direct creamery method. It was collected by straining through a muslin cloth after ghee making and stored under refrigerated conditions until further use.

Method of preparation of enrobed chocolate

For preparation of enrobed chocolate, dark chocolate (75% cocoa) and dark compound chocolate were weighed according to the respective treatment combinations and melted at 40-45 °C using a double-boiler to obtain a uniform molten chocolate mass. The required level of ghee residue was incorporated into the molten chocolate blend and mixed

thoroughly until a homogeneous coating was obtained. The prepared coating was used to enrobe the pre-prepared chocolate centres, maintaining a coating weight of 5 g per chocolate piece. Initially, a thin layer of melted chocolate was poured into a silicone mould to form the base coating, followed by the placement of the pre-prepared chocolate filling at the centre. The remaining melted coating was then added to ensure complete and uniform coverage of the filling. Finally, the enrobed chocolates were cooled at -15 °C for 15 min to facilitate proper setting and crystallization of the chocolate coating. The solidified chocolates were subsequently demoulded, wrapped in aluminium foil and stored under refrigerated conditions (7±2 °C) until further analysis.

Standardization of dark chocolate and dark compound chocolate ratio for coating

The coating composition was standardized in two stages. Initially, different proportions of dark chocolate (75% cocoa) and dark compound chocolate were evaluated to determine the suitable coating blend for enrobed chocolate preparation. The total coating weight was maintained at 5 g per chocolate piece, while the ratio of dark chocolate and dark compound chocolate was varied.

Five treatments were prepared by varying the proportion of dark compound chocolate (DCC) and pure dark chocolate (75% cocoa) (PDC) as given below:

Treatment	DCC: PDC	DCC (%)	PDC (%)
T ₁	0:100	0	100
T ₂	25:75	25	75
T ₃	50:50	50	50
T ₄	75:25	75	25
T ₅	100:0	100	0
DCC = Dark compound chocolate; PDC = Pure dark chocolate (75% cocoa)			

The coating blends were applied on the prepared chocolate centres by enrobing, maintaining a total coating weight of 5 g per chocolate piece. The prepared samples were evaluated for sensory characteristics, compositional properties and textural characteristics. The optimized chocolate blend was selected for further standardization of ghee residue incorporation.

Standardization of ghee residue level in chocolate coating

The selected chocolate blend (75% dark chocolate (75% cocoa) and 25% dark compound chocolate) was further standardized by incorporating different levels of ghee residue into the coating formulation. Four treatments containing 25, 30, 35 and 40 percent ghee residue in the coating were prepared.

The treatment details as given:

Treatment	Ghee residue in coating (%)
T ₁	25
T ₂	30
T ₃	35
T ₄	40

The total coating weight was maintained at 5 g per chocolate piece. The prepared samples were evaluated for sensory characteristics, moisture content, fat content and textural properties.

Sensory Evaluation

Sensory evaluation of enrobed chocolate samples was performed using a nine-point hedonic scale. A panel 10 judges evaluated the samples for colour and appearance, body and texture, flavour and overall acceptability. Samples were coded randomly and presented to the panel under controlled conditions.

Compositional Analysis

Moisture Content

The moisture content of the enrobed chocolate was estimated as per the procedure described in FSSAI (2024) [9]. The enrobed chocolate sample was first finely ground using a mortar and pestle to obtain a uniform and homogeneous mixture. Thereafter, an accurately weighed 2.0 g portion of the sample was transferred into a pre-weighed platinum or stainless-steel dish. The sample was evenly distributed and placed in a hot air oven maintained at 100±2 °C. This operation was repeated until the difference between two successive weighing is less than 1 mg; the lowest mass was recorded. The % moisture content in enrobed chocolate was calculated using the following formula:

$$\text{Moisture (\% (by weight))} = \frac{M1 - M2}{M1 - M} \times 100$$

Where,

M = The weight of the empty dish in gram.

M1 = The weight of the sample with dish before drying in gram.

M2 = The weight of the dish after drying measured in gram.

Fat Content

The fat content of enrobed chocolate was determined using the Soxhlet extraction method as per FSSAI (2024) [9] with some modification. The enrobed chocolate sample was first finely ground using a mortar and pestle to obtain a uniform and homogeneous mixture. An empty Soxhlet flask was thoroughly cleaned, dried and weighed accurately. The flask was then filled with approximately 350 mL of petroleum ether, which served as the extraction solvent. A 5 g portion of the prepared sample was accurately weighed and wrapped in Whatman filter paper No. 1 before being placed in a cellulose extraction thimble. The thimble was inserted into the Soxhlet apparatus and fat extraction was carried out continuously for 6-7 h using petroleum ether at a temperature of 35-40 °C. After completion of the extraction, the solvent was evaporated from the extract using a hot plate. The flask containing the extracted fat was then transferred to a hot air oven maintained at 100 °C for 1 h and dried to a constant weight until the difference between two successive weighing did not exceed 1 mg. The flask was cooled in a desiccator and weighed accurately. The fat content of the sample was calculated using the following formula:

$$\text{Fat(\% (by weight))} = \frac{M1 - M2}{M} \times 100$$

Where,

M = The weight of the sample taken in thimble in gram.

M1 = The weight of the extracted fat with Soxhlet flask after drying in gram.

M2 = The weight of the empty Soxhlet flask in gram.

Texture Profile Analysis

Texture profile analysis of enrobed chocolate samples was performed using a texture analyser. The samples were analysed for hardness, cohesiveness, springiness, gumminess, chewiness, adhesiveness and stiffness. Measurements were performed under controlled conditions and results were expressed as mean values of replicate observations.

Statistical Analysis

The experimental data were statistically analysed using analysis of variance (ANOVA). Treatment means were compared using the critical difference (CD) test at a 5% level of significance.

Results and Discussion

Effect of different ratios of dark chocolate (75% cocoa) and dark compound chocolate on the quality characteristics of enrobed chocolate

Effect of Dark Chocolate and Dark Compound Chocolate Ratio on Sensory Characteristics

The sensory scores of enrobed chocolates prepared with different proportions of pure dark chocolate (75% cocoa) and dark compound chocolate are presented in Table 1. Colour and appearance, body and texture and flavour scores did not differ significantly ($p > 0.05$) among the treatments, whereas overall acceptability was significantly ($p < 0.05$) influenced by the chocolate blend.

Colour and appearance scores ranged from 8.40 to 8.46, indicating that variation in the chocolate blend had no noticeable effect on the visual quality of the product. Body and texture scores ranged from 7.80 to 8.26, with treatment T₂ (75% pure dark chocolate + 25% dark compound chocolate) receiving the highest score. The balanced proportion of cocoa butter and vegetable fat probably contributed to a smoother texture and desirable firmness. Flavour scores ranged from 7.64 to 8.26, with treatments containing higher proportions of pure dark chocolate receiving comparatively higher scores because of their more intense cocoa flavour.

Overall acceptability ranged from 7.79 to 8.26, with T₂ recording the highest score followed by T₃. The superior acceptability of T₂ may be attributed to the balanced sweetness, cocoa flavour and desirable texture achieved through partial replacement of pure dark chocolate (75% cocoa) with dark compound chocolate. Therefore, T₂ was selected for further standardization.

These findings are in agreement with Mokbul *et al.* (2023) [13], who reported that partial replacement of cocoa butter with cocoa butter replacers maintained desirable sensory quality, whereas higher replacement levels adversely affected texture. Similarly, Biswas *et al.* (2017) [3] observed that variations in fat composition significantly influence texture and overall consumer acceptability of chocolate products.

Effect of Dark Chocolate and Dark Compound Chocolate Ratio on Compositional Characteristics

The moisture and fat contents of enrobed chocolates prepared with different chocolate blends are presented in Table 2.

Moisture content differed significantly ($p < 0.05$) among the treatments and decreased from 4.32% in T₁ to 3.11% in T₅

with increasing levels of dark compound chocolate. This reduction may be attributed to the lower moisture content of dark compound chocolate compared with pure dark chocolate.

Fat content also decreased significantly ($p < 0.05$), from 25.84% in T₁ to 19.94% in T₅. Pure dark chocolate contains a higher proportion of cocoa butter than dark compound chocolate, resulting in higher fat content in treatments containing greater amounts of pure dark chocolate.

Treatment T₂ exhibited 4.19% moisture and 24.48% fat, providing an appropriate balance between compositional characteristics and sensory quality for further investigation.

These findings agree with Konar *et al.* (2019) [10], who reported that the physicochemical properties of chocolate vary according to formulation. Beckett (2019) [2] also stated that the proportions of cocoa solids, cocoa butter and other ingredients markedly influence the moisture and fat composition of chocolate. Furthermore, Brown *et al.* (2023) [4] demonstrated that fat concentration significantly affects flavour perception and overall sensory acceptability of chocolate.

Effect of Dark Chocolate and Dark Compound Chocolate Ratio on Textural Characteristics

The textural properties of enrobed chocolates prepared with different chocolate blends are presented in Table 3.

Significant differences ($p < 0.05$) were observed for all textural parameters. Hardness ranged from 174.90 to 217.14 N, with T₁ exhibiting the highest hardness because of its greater proportion of cocoa butter, whereas T₃ showed the lowest hardness due to eutectic interactions between cocoa butter and vegetable fat. Cohesiveness and springiness were highest in T₃, indicating improved structural integrity and elasticity of the blended fat system.

Gumminess, chewiness and adhesiveness also reached their highest values in T₃, reflecting stronger internal bonding and a softer continuous fat phase. In contrast, stiffness ranged from 54.59 to 317.01 N/mm, with the highest value observed in T₅, indicating the formation of a more rigid crystalline structure due to the predominance of compound chocolate fat.

Although T₃ exhibited superior mechanical properties, T₂ was selected for further investigation because it combined desirable textural characteristics with the highest overall sensory acceptability.

These findings are comparable with those of Lonchamp and Hartel (2004) [12], who reported that blending cocoa butter with vegetable fats modifies crystallization behaviour through eutectic interactions, thereby affecting hardness and other mechanical properties. Similarly, De Clercq *et al.* (2017) [6] reported that fat composition influences chocolate firmness, elasticity and mouthfeel, while Biswas *et al.* (2017) [3] demonstrated significant effects of fat composition on hardness and rheological behaviour.

Effect of ghee residue on the quality characteristics of enrobed chocolate

Effect of Ghee Residue on Sensory Characteristics

The sensory scores of enrobed chocolates prepared with different levels of ghee residue are presented in Table 4. Colour and appearance and flavour were not significantly ($p > 0.05$) affected by ghee residue incorporation, whereas body and texture and overall acceptability differed significantly ($p < 0.05$) among the treatments.

Colour and appearance scores ranged from 8.29 to 8.74, indicating that incorporation of ghee residue did not adversely affect the appearance of the chocolate. Body and texture scores ranged from 7.54 to 8.74, with treatment T₃ (35% ghee residue) receiving the highest score. Moderate incorporation of ghee residue improved the smoothness and mouthfeel of the coating, whereas excessive incorporation reduced textural quality.

Flavour scores ranged from 7.74 to 7.95 and remained statistically similar among the treatments, suggesting that the levels of ghee residue used in the study did not adversely influence the characteristic chocolate flavour.

Overall acceptability ranged from 7.79 to 8.73, with T₃ recording the highest score followed by the remaining treatments. The superior acceptability of T₃ may be attributed to its desirable balance of texture, mouthfeel and flavour. Therefore, treatment T₃ (35% ghee residue) was selected as the optimum formulation.

These findings are consistent with those of Dua *et al.* (2018) [7], who reported that moderate incorporation of ghee residue improved the sensory quality of burfi, whereas higher levels reduced acceptability because of inferior texture. Similarly, Parth (2019) [14] observed that optimum incorporation of ghee residue enhanced overall sensory quality, while excessive addition adversely affected thabdi characteristics.

Effect of Ghee Residue on Compositional Characteristics

The compositional characteristics of enrobed chocolates containing different levels of ghee residue are presented in Table 5.

Moisture content increased significantly ($p < 0.05$) from 4.05% in T₁ to 5.21% in T₄ with increasing levels of ghee residue. This increase may be attributed to the relatively higher moisture content of ghee residue and its moisture-retaining properties.

Fat content also increased significantly ($p < 0.05$), ranging from 24.40% to 28.17%, owing to the high fat content of ghee residue.

Treatment T₃ exhibited 4.55% moisture and 26.69% fat, providing a desirable balance between compositional characteristics and sensory acceptability.

These findings are in agreement with Chaudhary (2017) [5], who reported an increase in fat content with increasing incorporation of ghee residue in burfi. Similar observations were reported by Prasad *et al.* (2012) [15], who found that progressive addition of ghee residue significantly increased the fat content of dairy confectionery products.

Effect of Ghee Residue on Textural Characteristics

The textural properties of enrobed chocolates prepared with different levels of ghee residue are presented in Table 6.

Hardness increased significantly ($p < 0.05$) from 98.69 to 177.47 N with increasing levels of ghee residue, probably because of the higher concentration of dispersed non-fat solids, which resulted in a denser particle network. Conversely, cohesiveness, springiness, gumminess, chewiness and adhesiveness decreased significantly with increasing levels of ghee residue. These reductions indicate weakening of the continuous fat crystal network and reduced elasticity of the chocolate matrix. Stiffness increased progressively from 18.90 to 77.80 N/mm, reflecting greater resistance to deformation at higher levels of ghee residue.

Although T₄ exhibited the highest hardness and stiffness, T₃ provided the most desirable combination of textural properties together with the highest sensory acceptability and was therefore selected as ghee residue enriched formulation for coating of enrobed chocolates.

These findings agree with Liang and Hartel (2004) [11], who reported that increased solid particle content enhances

chocolate hardness by reducing the mobility of the continuous fat phase. Similarly, Chaudhary (2017) [5] observed significant reductions in springiness, gumminess and chewiness with increasing levels of ghee residue in burfi.

Table 1: Effect of chocolate type on sensory characteristics of enrobed chocolate

Treatment (DCC: PDC)	Sensory score (9-point hedonic scale)			
	Colour and appearance	Body and texture	Flavour	Overall acceptability
T ₁ (0:100)	8.40±0.35	7.88±0.18	8.22±0.19	8.00±0.10 ^{ab}
T ₂ (25:75)	8.46±0.28	8.26±0.25	8.26±0.32	8.26±0.22 ^a
T ₃ (50:50)	8.40±0.40	8.20±0.17	8.23±0.17	8.23±0.20 ^a
T ₄ (75:25)	8.40±0.40	7.80±0.18	7.64±0.05	7.79±0.14 ^b
T ₅ (100:0)	8.45±0.30	7.91±0.38	7.93±0.58	7.92±0.11 ^b
SEm±	0.2	0.14	0.18	0.09
CD (0.05)	NS	NS	NS	0.30
CV%	4.17	3.1	3.99	2.05
Mean values±SD; Values within a column with different superscripts differed significantly ($p < 0.05$); n = 3; NS = non-significant; DCC = Dark compound chocolate; PDC = Pure dark chocolate (75% cocoa)				

Table 2: Effect of chocolate type on moisture and fat content of enrobed chocolate

Treatment (DCC: PDC)	Moisture (%)	Fat (%)
T ₁ (0:100)	4.32±0.23 ^a	25.84±0.07 ^a
T ₂ (25:75)	4.19±0.23 ^{ab}	24.48±0.20 ^b
T ₃ (50:50)	3.83±0.16 ^{bc}	23.03±0.77 ^c
T ₄ (75:25)	3.45±0.12 ^{cd}	21.42±0.74 ^d
T ₅ (100:0)	3.11±0.31 ^d	19.94±0.89 ^e
SEm±	0.12	0.36
CD (0.05)	0.4	1.14
CV%	5.94	2.75
Mean values±SD; Values within a column with different superscripts differed significantly ($p < 0.05$); n = 3; DCC = Dark compound chocolate; PDC = Pure dark chocolate (75% cocoa)		

Table 3: Effect of chocolate type on textural characteristics of enrobed chocolate

Treatment (DCC: PDC)	Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)	Adhesiveness (Nmm)	Stiffness (N/mm)
T ₁ (0:100)	217.14±5.22 ^a	0.004±0.001 ^c	0.91±0.05 ^c	0.87±0.02 ^d	0.8±0.08 ^d	0.49±0.12 ^d	187.24±2.54 ^b
T ₂ (25:75)	191.31±6.56 ^b	0.012±0.001 ^b	1.12±0.13 ^b	1.73±0.26 ^c	1.77±0.23 ^c	1.27±0.17 ^c	78.26±2.07 ^c
T ₃ (50:50)	174.9±2.22 ^c	0.017±0.002 ^a	1.49±0.17 ^a	3.18±0.33 ^a	5.69±0.61 ^a	2.75±0.19 ^a	64.76±2.61 ^d
T ₄ (75:25)	188.38±1.91 ^b	0.014±0.002 ^b	1.23±0.08 ^b	2.32±0.3 ^b	2.56±0.16 ^b	1.73±0.14 ^b	54.59±2.13 ^e
T ₅ (100:0)	209.37±6.48 ^a	0.002±0.001 ^c	0.66±0.02 ^d	0.57±0.15 ^d	0.29±0.17 ^d	0.25±0.07 ^d	317.01±2.89 ^a
SEm±	2.83	0.001	0.06	0.14	0.18	0.08	1.42
CD (0.05)	8.94	0.003	0.19	0.44	0.57	0.27	4.49
CV%	2.50	18.47	10.05	14.06	14.17	11.49	1.76
Mean values±SD; Values within a column with different superscripts differed significantly ($p < 0.05$); n = 3; DCC = Dark compound chocolate; PDC = Pure dark chocolate (75% cocoa)							

Table 4: Effect of the ghee residue on sensory characteristics of enrobed chocolate

Treatment (GR%)	Sensory score (9-point hedonic scale)			
	Colour and appearance	Body and texture	Flavour	Overall acceptability
T ₁ (25)	8.33±0.45	7.83±0.23 ^{bc}	7.74±0.51	7.79±0.32 ^b
T ₂ (30)	8.45±0.41	8.00±0.16 ^b	7.83±0.49	7.92±0.10 ^b
T ₃ (35)	8.74±0.31	8.74±0.21 ^a	7.95±0.41	8.73±0.15 ^a
T ₄ (40)	8.29±0.51	7.54±0.15 ^c	7.83±0.56	7.89±0.22 ^b
SEm±	0.21	0.09	0.24	0.10
CD (0.05)	NS	0.30	NS	0.33
CV%	5.10	2.44	6.36	2.71
Mean values±SD, Values within a column with different superscripts differed significantly ($p < 0.05$); NS = non-significant; n = 4; GR = Ghee Residue				

Table 5: Effect of the ghee residue on moisture and fat of enrobed chocolate

Treatment (GR%)	Moisture	Fat
T ₁ (25)	4.05±0.10 ^d	24.40±0.52 ^c
T ₂ (30)	4.32±0.13 ^c	25.78±0.73 ^b
T ₃ (35)	4.55±0.01 ^b	26.69±0.78 ^b
T ₄ (40)	5.21±0.18 ^a	28.17±0.47 ^a
SEm±	0.06	0.32
CD (0.05)	0.19	0.98
CV%	2.85	2.44
Mean values±SD, Values within a column with different superscripts differed significantly ($p < 0.05$); n = 4; GR = Ghee Residue		

Table 6: Effect of the ghee residue on texture characteristics of enrobed chocolate

Treatment (GR%)	Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)	Adhesiveness (Nmm)	Stiffness (N/mm)
T ₁ (25)	98.69±1.04 ^d	0.057±0.004 ^a	6.21±0.13 ^a	5.67±0.13 ^a	35.54±1.97 ^a	5.26±0.23 ^a	18.9±2.31 ^d
T ₂ (30)	101.41±1.36 ^c	0.046±0.003 ^b	5.14±0.94 ^b	4.47±0.94 ^{ab}	27.22±0.27 ^b	3.58±0.26 ^b	28.24±2.3 ^c
T ₃ (35)	138.13±2.46 ^b	0.024±0.007 ^c	2.24±0.47 ^c	3.4±0.47 ^{bc}	10.57±1.58 ^c	2.89±0.19 ^c	37.71±2.45 ^b
T ₄ (40)	177.47±2.09 ^a	0.017±0.003 ^c	1.88±0.58 ^c	3.07±0.58 ^c	5.47±0.66 ^d	1.85±0.39 ^d	77.80±1.45 ^a
SEm±	0.86	0.003	0.28	0.39	1.08	0.24	1.00
CD (0.05)	2.66	0.009	0.86	1.21	3.33	0.79	3.10
CV%	1.34	17.33	14.50	18.99	13.44	11.90	4.94
Mean values±SD, Values within a column with different superscripts differed significantly ($p < 0.05$); n = 4; GR = Ghee Residue							

Conclusion

The coating formulation significantly influenced the sensory, compositional and textural characteristics of the developed enrobed chocolate. Among the different combinations of pure dark chocolate (75% cocoa) and dark compound chocolate, the coating containing 75% pure dark chocolate and 25% dark compound chocolate (T₂) exhibited the highest overall acceptability with desirable flavour, texture and balanced compositional characteristics. Therefore, this chocolate blend was selected as the base coating for further standardization.

Optimization of the selected chocolate blend through incorporation of different levels of ghee residue demonstrated that the coating containing 35% ghee residue (T₃) produced the most acceptable enrobed chocolate. This treatment exhibited the highest overall sensory acceptability while maintaining desirable moisture, fat and textural characteristics. Even though, higher levels of ghee residue increased moisture, fat, hardness and stiffness, they adversely affected cohesiveness, springiness, gumminess, chewiness and overall sensory quality. Based on the overall findings, the coating formulation consisting of 75% pure dark chocolate (75% cocoa), 25% dark compound chocolate and 35% ghee residue was selected as the optimum coating formulation for the preparation of enrobed chocolate.

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